DEVELOPING RESEARCH AND PRACTICE

Beyond usability: designing effective technology implementation systems to promote patient safety

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Evidence is emerging that certain technologies such as computerized provider order entry may reduce the likelihood of patient harm. However, many technologies that should reduce medical errors have been abandoned because of problems with their design, their impact on workflow, and general dissatisfaction with them by end users. Patient safety researchers have therefore looked to human factors engineering for guidance on how to design technologies to be usable (easy to use) and useful (improving job performance, efficiency, and/or quality). While this is a necessary step towards improving the likelihood of end user satisfaction, it is still not sufficient. Human factors engineering research has shown that the manner in which technologies are implemented also needs to be designed carefully if benefits are to be realized. This paper reviews the theoretical knowledge on what leads to successful technology implementation and how this can be translated into specifically designed processes for successful technology change. The literature on diffusion of innovations, technology acceptance, organisational justice, participative decision making, and organisational change is reviewed and strategies for promoting successful implementation are provided. Given the rapid and ever increasing pace of technology implementation in health care, it is critical for the science of technology implementation to be understood and incorporated into efforts to improve patient safety.

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There is a growing recognition among those concerned with quality of care and patient safety that technology, especially information technology, may hold the key to improvements.[1–8] These new technologies have the potential to improve all aspects of healthcare delivery from diagnosis and treatment to administration and billing. The pace of new technology implementation in healthcare delivery has been accelerating over the years, and there is good reason to believe that this will not change in the near future because of pressures from government, purchasing groups, and consumers.[4 7–9] This pressure seems to be having an effect. Recent estimates suggest that up to 40% of US hospitals are planning to implement electronic order entry within the next 5 years[10] and a 2002 ISMP survey found that 50% of the responding hospitals were considering implementing bar coding technology.[11] With the pace of technology implementations likely to accelerate, it is imperative that healthcare delivery organizations understand how to maximize the potential benefits of patient safety technologies.

Human factors engineering science—which includes the study of technology design and evaluation—has shown that, for technology to be used effectively (that is, in the intended manner), it must be usable (that is, easy to use) by the potential end users.[12 13] Among patient safety scientists and practitioners, technology usability is becoming accepted as a necessary component of design to ensure that new technologies are used effectively; this is clear from the number of recent publications on the topic in the healthcare literature.[14–19]

While there is clear evidence that, for technologies to be used effectively they must be designed to be usable (that is, easy to use) and useful (that is, will improve job performance, efficiency, and/or quality),[20–23] the evidence is also clear that design does not end once usability and usefulness are addressed.[24–26] The way that technology is implemented into an organisation must also be designed properly to increase the probability of effective use. Studies of technology adoption and acceptance in health care are beginning to appear in the literature, which is a sign that the importance of implementation is becoming more recognised.[27–36] The purpose of this paper is to present the argument that the design of technology implementation—separate from usability considerations—may independently determine the extent to which end users accept and use new technologies such as those designed to improve patient safety.[25 37–42]

UNDERSTANDING THE IMPACT OF NEW TECHNOLOGY ON END USERS

The effects of new technology on users, the organisation, and work processes are dependent on many factors. For example, new technology will often change how jobs and tasks are accomplished, the extent of division of labour, the span of organisational control, and the degree of coordination.[43 44] The changes themselves may be for the better, but they are changes nonetheless. Because so much typically does change with the introduction of new technology, employee resistance is likely which may reduce or prevent the effective use of the technology.

Resistance to change is a complex phenomenon and several theories have been proposed to explain it. Equity implementation theory[45] suggests that users assess changes in terms of gain

or loss in equity status, compare their relative outcomes with that of the organisation, and compare their relative outcomes with other users. Changes perceived as being favourable—for example, if the administration of bar coded medication results in faster and safer medication administration—will be accepted, and changes viewed as unfavourable—for example, if medication administration takes longer—will be resisted.

Attribution theory has also been used to explain end user resistance to new technology.[46] The model posits that the introduction of new technology, the external environment, and internal interpersonal influences combine with previous success or failure with implementing new technologies to influence causal attributions. The attributions can influence expectations of what will happen during and after the implementation. This then may affect affective and behavioural reactions to the use of the new technology. In fact, there is empirical support that previous negative experiences with information technology can lead to the rejection of new systems.[47] Taken together, the two theories posit that, if an implementation is designed such that potential end users (nurses, physicians, pharmacists, etc) believe that (a) their jobs will change for the worse, (b) their work will become worse relative to another group, (c) the organisation is benefiting from the new technology at their expense, or (d) this change will be as bad as previous changes, there is an increased likelihood that end users will reject the new technology. It is therefore clear that, even if a technology is user friendly, the design of the implementation will be at least as critical in determining end user acceptance and effective use.

THE SCIENCE OF DESIGNING NEW TECHNOLOGY IMPLEMENTATION

Several decades of research have helped to provide empirical evidence showing what types of design practices help to create technology implementation processes that are likely to promote end user acceptance and effective use of new technologies. Major contributions come from the studies of technology acceptance, technology implementation, diffusion of innovations, organisational justice, participative decision making and technology/organisational change. Key research from these areas will be discussed to make the case that the science of implementation does, in fact, exist and should be used to design technology implementation processes.

The questions that need to be addressed first are: (1) why focus on the notion of ''design'' and (2) what does it mean to design a technology implementation? The first question is central to the goal of patient safety and reflects decades of work in safety outside health care. There are two main ways to approach safety goals—reactive approaches and proactive approaches. The reactive approaches are certainly most well known in health care, as was seen in a recent debate on whether to focus patient safety efforts on errors or injuries.[48 49] Both approaches are primarily reactive in that data on errors or injuries must first be collected so that prevention efforts can be implemented. An entirely different approach is to be proactive and not wait for either errors or injuries, but rather to focus on making sure that existing systems are designed to prevent errors or injuries from happening in the first place. There is a well known science to such design which is known as human factors engineering.[50] As far as the second question is concerned, design is typically thought of in terms of products (such as software, IV pumps, surgical tools) but also applies to processes. The methods by which technologies are implemented into organisations are all processes and they will either be designed well or poorly. The review of the key literature contributing to our understanding of how to design an implementation will show that process design principles and guidelines exist which can be

followed to reduce the likelihood of technology rejection and increase the likelihood of acceptance.

WHAT PREDICTS WHETHER PEOPLE INTEND TO USE NEW TECHNOLOGIES?

For several reasons the literature on how to design technology implementation processes appropriately has mostly focused on one of two outcomes: (a) satisfaction with technology and (b) willingness to use the technology which is typically discussed as ''technology acceptance'' and/ or ''behavioural intention to use''.[20–22 51] The former is typically used when the technology being studied is mandatory—that is, end users do not have a choice in using the technology. This is the typical situation in health care, as in the case where a hospital replaces its IV pumps with Smart IV pumps. Willingness to use the technology is used most often when the technology is voluntary—that is, users have a choice to use it (for example, physicians can choose to use electronic order entry or to hand write prescriptions). These two measures are used more often than measures of actual use because it is much simpler to measure satisfaction, acceptance, or intention to use—which can be measured with validated survey items—than it is to measure actual use. Strong cases have been made in theories such as the theory of reasoned action, the transtheoretical model, diffusion of innovations, and the theory of planned behaviour that the best predictor of actual behaviour is behavioural intentions,[52–56] suggesting that the more simple to measure construct of behavioural intention or acceptance might be a reasonable proxy measure of actual use in voluntary environments. In environments where the use of a particular technology is mandatory—for example, the replacement of paper records with electronic medical records—satisfaction with technology is thought to be related to performance with the technology. Because similar variables have been found to predict both technology acceptance with voluntary technologies and technology satisfaction with mandatory technologies (although the strength of the relationships between variables does differ in the two environments[57]), the terms ''acceptance'' and ''satisfaction'' will be used interchangeably for the remainder of the paper. An important question to answer for understanding how to design technology implementation processes is therefore—what affects technology acceptance or satisfaction? These factors should illuminate design criteria for implementation processes.

Organisational factors

Organisational factors that have been found to predict end user technology acceptance focus on decisions made by management related to how a new technology will be implemented.[32] One such factor is how well the new technology will be integrated with existing technologies, workflow, the environment, and other social systems.[58 59] For example, if a hospital plans to implement electronic order entry, there will be integration issues related to medical records, pharmacy information systems, current methods of ordering and dispensing medications, space for computer terminals, lighting, and workflow. Technical system changes cannot be designed in isolation from the subsystems involving humans, and technical systems must fit within the constraints of the environment. What that means is that, if a new technology does not work well with other existing technologies end users must use, is not usable in the existing environment (for example, lack of space or lighting causes glare), or does not positively impact workflow, resistance to the new technology is likely.

Management commitment to the new technology and the implementation process has also been found to be an important predictor of the success of the change.[26] This

commitment needs to be shown through specific actions. For example, the reason(s) for the new technology should be made clear in order to reduce uncertainty about the necessity of the new technology and to foster positive attitudes toward the technology.[60] Clarity in the reasons for the new technology also facilitates the development of measures of success as well as accountability for the change.

Another indicator of management commitment and good planning is the presence of a structured program for implementation.[26 58 60] A structured program might take a variety of forms including a multidisciplinary transition team, clear direction for end users and managers as to where to go for help, and structured communication networks between supervisors and workers to deal with the new technology. A well designed structure indicates that the organization is ready for the change to the new technology, which may serve to reduce the likelihood of resistance.[61]

Perhaps the two most often studied and empirically supported organizational factors that can promote the acceptance of technology by the end users are training and participation. The science of training is well established.[62–64] Not surprisingly, well designed training programs have been shown to promote end user acceptance of technology.[23 65 66] The key is to design the training program according to the scientific evidence. Well designed training not only transfers knowledge and skills about the technology, but it can also bring understanding of the technology through education and can create feelings of involvement in decisions.[67] In addition, training can lead to several other important variables for the acceptance of technology including self-efficacy[65 68] and intrinsic motivation.[23 66]

Just as well designed training can improve the likelihood that the technology will be accepted, appropriately designed end user participation in the implementation of new technology can also increase the likelihood of acceptance.[25 44 69 70] There are several possible reasons why end user participation in new technology decisions improves acceptance. Empirical evidence suggests a link between participation and improved performance,[71–73] job satisfaction,[74] role strain,[75] commitment,[74] and reduced stress,[76] although the strength of evidence and reasons for the findings of at least the first two have been widely debated.[77] Those relationships might suggest that participation improves the likelihood of technology acceptance by improving end user job satisfaction and performance at a time when both are likely to be suffering, and also possibly because the stress caused by the change is buffered.

Underlying these empirical findings are theoretical reasons that might explain the positive effects of participation. The two dominant theories for the effects of participation on outcomes are the motivational and cognitive models.[78 79] The motivational model suggests that participation improves commitment, trust, and control while reducing resistance to change and anxiety, therefore having a motivational effect on employees. Such would be the case if nurses and pharmacists were involved in designing and implementing a point of care bar code system and, because they felt management trusted them, they became motivated to use the product. On the other hand, the cognitive model proposes that the positive effects of participation are due to increases in information and knowledge which reduce uncertainty. An example of this would be if the nurses and pharmacists gained valuable information about the technology through their participation and were thus less anxious about the proposed change. While there is debate as to which of the theories explains the impact of participatory processes, both make a clear case as to why employee participation in the implementation of new technology should increase acceptance. In addition, participation leads to increased social interaction which may facilitate social support. Social support alone may have direct effects in reducing stress and improving health,[80 81] although the evidence is not consistent.

Research that has looked specifically at the role of participation in the implementation of new technologies has found positive outcomes. Empirical evidence exists for participation leading to higher levels of acceptance of the new technologies and lower levels of dissatisfaction and stress,[76] as well ratings that newer systems were better than older ones, that implementation schedules were more reasonable, and that the attitudes of the implementation team and managers towards the implementation were more favourable.[82] While other studies continue to show results supportive of the positive impact of end user participation on technology acceptance,[83 84] negative results have also been found.[85] Negative findings may be due to participation not being useful in all situations or to specific studies being impacted by the many well known limitations and potential problems with participation.[37 70 86 87]

Organisational justice—another organisational factor important for new technology implementation—is broadly defined as the fair treatment of employees. It is often described as being composed of distributive, procedural, and interactional justice. Distributive justice perceptions are based on the distribution of outcomes of decisions,[88] procedural justice focuses on the fairness of how decisions are made,[89 90] and interactional justice refers to how employees in an organization treat those below them or subject to their authority. Processes that show fairness in decision making include (1) following consistent procedures, (2) using non-biased decision making, (3) using accurate information, (4) having the opportunity to correct mistakes, (5) having all interested parties represented, (6) using ethical criteria, and (7) giving advanced notice.[91 92] Cobb et al[90] added giving the employees a voice in the establishment of ground rules or procedures to be used in the change process, which is the same as participation. Procedural concerns may be more significant in the long term as employees consider how to maintain or prevent outcome patterns which are perceived as favourable or unfavourable.[93] It is natural that issues of justice arise in any change process since change may cause stress and loss.[90]

When workers see themselves being treated fairly, they may develop attitudes and behaviours necessary for successful change even under conditions of adversity and loss.[90] Addressing justice issues is therefore one key to successfully implementing organisational change.[94 95] Empirical evidence supports the importance of justice perceptions for accepting or being satisfied with new technology[96] as well as for accepting or being satisfied with other types of changes such as organisational downsizing, job classification restructuring, facility relocation, and technology interface development.[92 93 97–99]

Technology factors

The technological characteristics most often studied and linked to technology acceptance are response time, flexibility, breakdowns or crashes, usability or ease of use, and usefulness. The last two have been the most thoroughly researched because they are both central to the technology acceptance model (TAM),[20–23 51 100–104] the most thoroughly studied theory of technology acceptance. The concept of usefulness is not only determined by technological design but also by selection which is a management decision. Nevertheless, it is being categorized here as a technology factor because end user perceptions of usefulness are tied to the performance of the technology.

Ease of use and usefulness of technology are the key determinants of acceptance according to the TAM.[100] As

Table 1 Implementation design principles and predictors of technology acceptance

Variables affecting success of implementation	Top management commitment	Responsibility/ accountability	Structured program	Training	Pilot testing	Communication and feedback	Simulation	End user participation
Uncertainty about change	×	×	×	×	×	×	×	×
Work changes	×		×	×	×	×	×	×
Resistance to change	×		×	×	×	×	×	×
Lack of control	×	×	×	×	×	×	×	×
Ease of use	×			×	×	×	×	×
Usefulness	×		×	×	×	×	×	×
Subjective norms	×	×	×			×		×
Self-efficacy	×			×	×	×	×	×
Integration	×		×			×		×
Justice	×	×	×	×	×	×	×	×
Readiness for change	×	×	×	×	×	×	×	×
Technology design	×	×	×	×	×	×	×	×

×, variables dealt with by each design principle.

characterised within the TAM, usefulness is a measure of the indirect impact of technology on acceptance because it is an indication of the extent to which users believe a technology will help them perform their job better. If a physician thought that a computerised decision support system would help him or her to avoid incorrect orders, then the technology might be perceived as useful. Ease of use, or usability, was proposed to impact acceptance by improving end user self-efficacy—that is, for example, to the extent that a point of care bar coding system for medication administration is easy for nurses to use, they will gain confidence in their ability to administer medications with the technology and hence be more satisfied with it. Subsequent research has confirmed that both constructs are predictors of acceptance, with usefulness being the stronger predictor.[20 21 23 105–107]

Most of the research on the TAM, however, has examined technologies that could be used voluntarily but, in health care, many implementations result in more mandatory use of new technology. Recent research examining technology acceptance for mandatory technologies has found mixed results. In some cases the original TAM holds[51] but, in others, ease of use appears to be a better predictor of outcomes than usefulness[57] while, in yet others, neither perceived ease of use nor usefulness predicted behavioural intentions.[108] Evidence has also shown that what predicts end user satisfaction or acceptance of a technology changes over time with greater use of the technology.[109] Regardless of whether usefulness, ease of use, and/or another variable such as self-efficacy are the main determinants of acceptance among mandatory technologies, the same basic implementation design principles will apply, as will be discussed later.

Technology characteristics such as response time, flexibility, breakdowns or crashes, and usability have been proposed to have both direct and indirect effects on technology acceptance.[110] The direct effect hypothesis suggests that well designed technologies will be more likely to be accepted than those perceived to be poorly designed. The indirect hypothesis proposes that technology changes the nature of work, and end users then react to the changes in work. The indirect hypothesis has received support in the job stress literature, which has shown that new technologies can lead to changes in workload and job control which can then affect stress levels.[111–113]

Job factors

The degree of job change caused by the implementation of a new technology is also an important issue. Earlier discussions in this paper explained how new technologies may change job structure and therefore influence perceptions of the technology, and there is empirical evidence to confirm the proposition. Specifically, research has found that perceptions of negative impacts on users were found more often when new technology implementations led to greater changes in work structure.[114] Most patient safety technologies are likely to lead to significant job changes. For example, point of care bar coded medication administration systems have the potential drastically to change the way nurses dispense, administer, and document medications.

Individual factors

Several individual difference variables have been found to predict technology acceptance. Self-efficacy, as it relates to new technologies, refers to user perceptions that they are confident they can successfully use the new technology. Empirical evidence shows that computer self-efficacy can

Table 2 Implementation design principles with explanations

Design principle	Reason for importance
Top management commitment	Enables additional design principles
Responsibility/ accountability	Effective in promoting success because it shows the importance of the change and lets end users know who to go to with ideas or concerns
Structured program	Provides end users with a ''road map'' which can reduce uncertainty and promote feelings of control. It reduces many of the fears associated with new technology: end users will know why the change is coming, what to expect, when to expect it, where to expect it to happen, and who will be in charge
Training	Targets self-efficacy, ease of use, and usefulness explicitly, but also reduces uncertainty and fear and promotes control because users gain knowledge and skills
Pilot testing	Involves users with the technology and creates a test bed to uncover and solve problems. It also promotes an understanding of integration needs. Pilot testing should be done in a sufficient number of locations so that the results can be applied to the remainder of the facility
Communication	Early communication about intentions is necessary to begin to reduce uncertainty. Clear communication about decisions is necessary for the same reason and to promote perceptions of procedural justice. There also needs to be clear and open communication channels between prospective end users, decision makers, and technical support
Feedback	Feedback on end user concerns and ideas must be provided quickly so that they know they are being taken seriously. Staffing a help desk accessible in person, by telephone, or over the computer with knowledgeable staff at all times when people are engaged in using the technology is one way to ensure prompt feedback
Simulation	Simulation should be used before, during, and after an implementation. On all three occasions it promotes self-efficacy, usefulness, ease of use, and control while reducing the variety of fears that can exist. Simulation here refers to having the actual technology available to use in the intended manner, but without the possible negative consequences. During and after implementation a simulation room that has the technology operational and allows users to engage the technology without fear of adverse outcomes is important
End user participation	Enhances perceptions of justice, self-efficacy and control, reduces a variety of fears and uncertainty. May have both cognitive and motivational components

variables (for example, ease of use, perceptions of others) being more important for older workers.[102] Gender has also been found to be a moderator; for women, ease of use and subjective norms are critical while, for men, usefulness is important.[104] It might seem that, since these factors are beyond the control of the organization, they can be ignored. This is not the case. But that does not mean having to create separate implementation processes for each employee. Implementation processes that follow the design guidelines will, in fact, accommodate the range of needs of men and women, young and old, experts and novices.

DESIGN PRINCIPLES FOR SOUND NEW TECHNOLOGY IMPLEMENTATION PROCESSES

The research reviewed can be translated directly into design guidelines for implementation processes. Table 1 presents a matrix of guidelines together with the major predictors they affect. The assumption underlying the table is that the design principles presented will only positively affect the predictors of success if they are designed properly. As can be seen, most of the design principles can have a positive impact on most, if not all, of the predictors of acceptance. That does not mean that an organization can simply choose one of the principles that affect all of the predictors. Each of the design principles affects predictors through specific mechanisms so they are all important. Commitment of top management is the most crucial because it enables the resources for implementing each of the other principles (box 1). Table 2 provides a list of the design guidelines together with specific explanations of why each is important.

CONCLUSIONS

For the foreseeable future, healthcare organizations will face pressures to implement technologies that have the potential to reduce medical errors. While in theory such technologies (such as CPOE) should be able to reduce medical errors, this will only be the case if the technologies are user friendly and designed to help healthcare providers do their jobs better. But even that may not go far enough to promote user satisfaction with, and effective use of, these technologies. Technology implementation processes must also be designed according to

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Key messages

- Designing patient safety technologies such as computerized provider order entry or bar coded medication administration systems to be usable (easy to use) and useful (will improve job performance, efficiency, and/ or quality) is necessary but not sufficient to ensure that the full safety benefits of the technologies can be achieved.
- In addition to usability and usefulness, technology should be implemented according to the science of technology implementation to promote effective technology use (that is, the technology is used in the manner intended) and satisfaction.
- There are a number of specific design principles that can improve the design of technology implementations.
- These include having somebody responsible and accountable for the success of the implementation, conducting pilot testing of the system in a sufficient number of locations so that the results can be applied to the remainder of the facility, and seeking appropriate end user participation in all phases of the implementation.

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have an impact on intentions to use computers.[65 68 115] Level of education and previous experience with similar technology has been found to influence perceived ease of use which affects acceptance.[107] Age has been found to be an important moderator for acceptance and sustained use, with attitudinal factors (for example, effect on performance) being more important for younger workers and social and process

scientific principles if the patient safety potential of these technologies is to be realized. Healthcare organizations that ignore implementation design principles increase the risk that users (physicians, nurses, pharmacists) will reject the technologies that could ultimately improve patient safety. Given the high cost of patient safety technologies, healthcare organizations can ill afford to make such mistakes.

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